10.1 INTRODUCTION

In the context of this report, "synthesis" refers to the process by which the findings of the individual modules are considered together to determine how the cumulative effects of forest practices and other land uses may affect fish habitat, water, and capital improvements of the state. Conclusions from each module have been provided in the individual module chapters: Mass Wasting (Section 3.0), Surface Erosion (Section 4.0), Hydrologic Change (Section 5.0), Stream Channels (Section 6.0), Riparian Function (Section 7.0), Fish Habitat (Section 8.0), and Water Supply / Public Works / Water Quality (Section 9.0). For analysis of the interaction of various watershed processes via the channel network, refer to the Stream Channel module (Section 6.0).

10.2 ROUTING / INDICATOR AREAS

One purpose of synthesis is to evaluate the deliverability of input variables (sediment, water and wood) to vulnerable resources. Deliverability is determined by assessing the routing of an input from the source to the channel, and the channel capacity to route input variables to areas where potential resource effects are expected. If deliverability exists and adverse change to the resource would result, the specific hazard is identified as a "resource sensitivity" (Section 10.3).

Three areas in the WAU have been identified as areas of special concern. The first area is comprised of alluvial fans situated between Stewart Mountain and the South Fork Nooksack River. In these areas, coarse sediment, debris torrents, fine sediment, and LWD may be routed from unstable hillslopes (Mass wasting maps units [MWMU] #1, #2, #3, and #10) through mountain channels (Segment 7) and deposited in and along alluvial fan reaches (Segments 5 and 6), typically via debris torrent. The greatest resource sensitivity is on the alluvial fan of Jones Creek, which contains a public bridge and a public school, along with fish habitat. Fish habitat, public bridges and private property are similarly vulnerable along lower Sygitowicz, Hardscrabble, and McCarty Creeks.

The second area of concern is comprised of the mainstem and side channels of the South Fork Nooksack River (Segments 1 and 2). In these areas fish habitat is impaired by low instream LWD concentrations and riparian forests have low LWD recruitment potential. Recorded summer peak stream temperatures may exceed the metabolic optimum for salmonids (Section 7.0). The highest recorded temperature has been measured closely upstream of the point where the South Fork Nooksack enters the WAU, but high temperatures are sustained within the WAU due to channel modifications and low riparian shade.

Over the past century, riparian function along the South Fork Nooksack has been progressively impaired by loss of riparian conifer forests. Agricultural development and channel manipulations have greatly reduced the total length of side channels and led to reduced channel structural diversity (Section 6.0).

The third area of concern involves inputs of fine sediment from logging roads on the southern Van Zandt dike (SE sub-watershed) to the Black Slough, a valley bottom stream. The estimated volume of fine sediment delivered from the mainline and spur roads to headwater streams is substantial. These sediments are routed through tributaries to the Black Slough, where they may impact fish habitat through increased turbidity and/or sedimentation. The Black Slough is a very low gradient channel which retains fine sediment rather than routing it to the South Fork Nooksack. Resource impacts from this problem appear to be less severe in comparison to the two previously mentioned situations, and physical evidence of impacts was considerably less apparent.

Triggering mechanisms and contributing activities associated with delivered hazards are described in the causal mechanism reports (Section 11.2) The analysis team found that routing of input variables could be described according to the following rules:

1. Channel aggradation, coarse sediment, debris flows, fine sediment, and LWD could be routed from source areas in MWMU #1, #2, #3, #4, #5, #7, and #10 through channel segment 7 and deposited in channel segments 5 and 6 (alluvial fans and channels immediately downstream of fans). Fine sediment could be further routed to channel segments 1 and 4 (South Fork Nooksack and its floodplain tributaries).

2. Coarse and fine sediment could be routed from MWMU #9 (deep-seated landslides) and deposited in channel segments 5 and 6. Fine sediment could be further routed to channel segments 1 and 4.

3. Rockfall and debris flows could be routed from MWMU #6 and deposited in channel segments 5 and 6.

4. Fine sediment could be routed from roads in the northwest, southwest, and southeast sub-watersheds and deposited in Black Slough (a part of channel segment 4) and the South Fork Nooksack and its floodplain tributaries (channel segment 1).

5. Reduced near-term LWD recruitment potential poses a hazard in channels adjoining all RCUs with low or moderate recruitment potential, representing portions of channel segments 1, 2, 4, 5, 6, 7 and 8 (all channel segments included in the network of fish-bearing streams). All channel segments have been rated responsive to wood input. Since existing pool frequency is low, LWD is assumed to be a delivered hazard.

6. Below-target riparian shade poses a hazard in channels adjoining all RSUs with low shade, also representing portions of channel segments 1, 2, 4, 5, 6, 7 and 8 (all channel segments included in the network of fish-bearing streams, and certain contributing Type 4 streams). Maximum summer temperatures

exceeding the Class A water quality criterion have been observed in channel segments 1 and 5. Since these locations are associated with areas of low riparian shade, riparian shade is assumed to be a delivered hazard.

Routing was not found to occur in the following cases:

7. MWMU #7 is conditionally a high hazard because it contains unmapped inclusions of MWMUs #1, #2, #3 #4, #5, and possibly #6 that could not be accurately mapped at the required scale. The analysis team found that a field determination of hazard unit boundaries would be required prior to conducting forestry operations in this unit. The field determination by the applicant would delineate areas meeting the definition of high-hazard MWMUs and the area would be subdivided into high-hazard and low-hazard portions, at which point the routing principles identified above (#1 and #2) would take effect.

8. The impacts of LWD recruitment potential and canopy cover hazards were assumed to occur locally, and not to be routed beyond the limits of any specific riparian condition or riparian shade unit.

9. Areas rated as Low hazards (MWMU #8, surface erosion from sources other than roads in the southeast, southwest, and northwest sub-watersheds, and peak flow changes) were assumed not to be routed or to be routed without a material adverse effect on vulnerable resources.

10.3 RESOURCE SENSITIVITY

If a hazard could deliver an input variable to a resource in such quantitity as to adversely affect the resource, then the hazard was delineated as a specific resource sensitivity. The ten Resource Sensitivity Areas (four mass-wasting, one surface erosion and five riparian function) identified for the Acme WAU are listed in Table 10-1 and their locations are shown in Figure 10-1. Causal Mechanism Reports for each resource sensitivity are included in Prescriptions (Section 11.2). Hillslope areas where standard forest practice rules apply are listed in Table 10-2.

10.4 RULE CALLS

Rule calls were derived on the basis of the cumulative effects rule matrix (WAC 222-22), which links each resource vulnerability ratings with associated rating for the likelihood of adverse change and deliverability to determine the required "rule call." The analysts recognize that resource vulnerability to any given input variable (coarse sediment, fine sediment, peak flow, LWD, or stream temperature) will vary over time and with respect to the magnitude of the delivered input, and incorporated this

Table 10-1. Resource Sensitivity Areas delineated in the Acme WAU.

RESOURCE SENSITIVITY AREA	MAP UNIT	INPUT VARIABLES	CHANNEL SEGMENT	HILLSLOPE HAZARD	RESOURCE VULNERABILITY	RULE CALL
MASS WASTING						
RSA MW-1	#1, 2, 3, 4, 5, 7, 10; see Section 11.1 for remarks on unmapped inclusions.	CS, FS	5, 6	H / M / L	H	Prevent or Avoid
RSA MW-2	#6	DF, RF, CS	5, 6	H / L	H	Prevent or Avoid
RSA MW-3	#9	CS, FS	1, 4, 5, 6	H / M	H	Prevent or Avoid
SURFACE EROSION						
RSA SE-1	SE, SW, and NW SUB-WATERSHED	FS	4	H / M	H	Prevent or Avoid
RIPARIAN FUNCTION						
RSA R-1	RCU #: 1, 2, 3, 4, 5, 6, 7, 11, 12, 13, 14, 19, 38, 39, 40, 41, 51, 52, 55, 56, 57, 62, 63, 64, 65, 66, 75, 76, 77, 78, 93, 94, 95, 96, 97	LWD	1, 2	H / M	H	Prevent or Avoid
RSA R-2	RCU #: 6, 10, 15, 16, 17, 18, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 37, 42, 43, 44, 45, 46, 47, 48, 53, 54, 71, 72, 73, 79, 80, 81, 82, 85, 86, 87, 88, 89, 90, 91, 92, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109	LWD	4, 6	H / M	H	Prevent or Avoid
RSA R-3	RCU #: 6, 8, 9, 10, 35, 36, 37, 44, 45, 49, 50, 53, 54, 58, 59, 69, 70, 73, 74, 83, 84, 91, 92, 108	LWD	5	H / M	H	Prevent or Avoid
RSA R-4	RCU #: 69, 70, 83, 84, 112, 113, 115, 116	LWD	7, 8	H / M	H	Prevent or Avoid
RSA R-5	RSU #: 1, 2, 3, 6, 7, 8, 9, 11, 12, 13, 14, 16, 18, 20, 21, 23, 26, 28, 29, 30, 31, 32, 34, 35, 36, 37, 38, 39, 41, 42, 43	Shade	1, 2, 4, 5, 6, 7, 8	H	H	Prevent or Avoid
WATER QUALITY						
WQ-1	WQ-1	Shade		H	H / M	Prevent or Avoid

Input Variable: CA = channel aggradation; CS = coarse sediment; DF = debris flow; FS = fine sediment; LWD = large woody debris; RF = rockfall; Shade = canopy cover

Table 10-2 Hillslope areas in the Acme WAU where standard rules apply.

HILLSLOPE AREA	MAP UNIT	INPUT VARIABLES	CHANNEL SEGMENT	HILLSLOPE HAZARD	RESOURCE VULNERABILITY	RULE CALL
MASS WASTING						
MWHU #L	#8, part of 7: see Section 11.1 for details.	CS, FS	All	L	H	Standard Rules
SURFACE EROSION						
Road	NE and LOWLAND SUB-WATERSHEDS	FS	All	L	H	Standard Rules
Hillslope #L	ALL UNITS	FS	All	L	H	Standard Rules
HYDROLOGIC FUNCTION						
Hydrology	ALL AREAS	PF	All	L	L	Standard Rules
RIPARIAN FUNCTION						
LWD	RCU #: 20, 21, 60, 61, 67, 68, 110, 111	LWD	4, 5, 7	L	H	Standard Rules
Shade	RSU #: 4, 5, 10, 15, 17, 19, 22, 24, 25, 27, 33, 40, 44	Shade	4, 5, 6, 7, 8	L	H	Standard Rules

Input Variable: CS = coarse sediment; FS = fine sediment; LWD = large woody debris; Shade = canopy cover

consideration where possible. Required management actions (i.e., rule calls) are listed in Tables 10-1 and 10-2.

10.4.1 High Hazard Areas

All ten resource sensitivity areas shown in Table 10-1 include in high hazard areas. Public resources vulnerabilities have been described in Section 8.0 (Fish Habitat) and Section 9.0 (Water Supply / Public Works / Water Quality).

Following the rule matrix, ten resource sensitivity areas received prevent or avoid management calls. Specific prescriptions designed to prevent land management activities from triggering hazards are provided and justified in Section 11.0 (Prescriptions).

The resource sensitivity areas specific to riparian function (LWD and shade) only affect hazards locally. Prescriptions for these areas are not likely to affect fish habitat vulnerabilities in other channel segments.

10.4.2 Moderate Hazard Areas

One resource sensitivity area, affecting surface erosion, is included in a moderate hazard area (Table 10-1). Resource sensitivity area SE-1 receives a prevent or avoid management call due to high fish resource vulnerability to fine sediment delivery.

Several of the mass-wasting and riparian function resource sensitivity areas described above as high hazard also include some areas of moderate hazard. In every case, the moderate hazard was linked with a high fish resource vulnerability, resulting in a prevent or avoid management call.

10.5 CONFIDENCE EVALUATION

The conclusions stated herein were based on multiple sources of evidence brought forth in each of the modules. We attempted to use the weight of the evidence in reaching conclusions when evidence was incomplete or consequences unclear. Confidence is high that resource impacts from forest practices have been correctly identified by this synthesis process.